MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

THE *K*-GROUP MAXIMUM-FLOW NETWORK-INTERDICTION PROBLEM

Ibrahim Akgun-First Lieutenant, Turkish Army
B.S., Turkish Army Military Academy, 1994
Master of Science in Operations Research-March 2000
Advisor: R. Kevin Wood, Department of Operations Research
Second Reader: Gerald G. Brown, Department of Operations Research

The *K*-group network-interdiction problem (KNIP) in which a "network user" attempts to maximize flow among $K \geq 3$ "node groups' while an "indicator" interdicts (destroys) network arcs, using limited interdiction resources, to minimize this maximum flow was studied. Two models were developed to solve or approximately solve KNIP.

The multi-partition network-interdiction model (MPNIM) is an approximating model. It partitions the node set *N* into *K* different subsets, each containing one prespecified node group, and interdicts arcs using limited resources so that the total capacity of uninterdicted arcs crossing between subsets is minimized. The multi-commodity network-interdiction model (MCNIM) explicitly minimizes the maximum amount of flow that can potentially be moved among node groups using *K* single-commodity flow models connected by joint capacity constraints. It is a min-max model but is converted into an equivalent integer program MCNIM-IP.

Both MPNIM and MCNIM-IP are tested using four artificially constructed networks with up to 126 nodes, 333 arcs, *K*=5, and 20 interdictions allowed. Using a 333 MHz Pentium II personal computer, maximum solution times are 563.1 seconds for MPNIM but six of 16 MCNIM-IP problems cannot be solved in under 3,600 seconds.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Electronics Warfare, Modeling and Simulation

KEYWORDS: Network Interdiction, Minimizing Maximum Flow, Node Isolation, Integer Program

SCREEN DISPOSITIONS OF NAVAL TASK FORCES AGAINST ANTI-SHIP MISSILES

Erhan Aydin-Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1994
Master of Science in Operations Research-March 2000
Advisor: Arnold H. Buss, Department of Operations Research
Second Reader: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

Ship defense in convoy operations against Anti-Surface Missiles (ASM) has been an important aspect of Naval Warfare for the last two decades. Countries in a state of conflict often conduct threatening operations in their own territories in order to slow or stop the enemy merchant ship traffic through the straits or littoral waters. Such littoral scenarios, the quantity and capability of ASMs in non-NATO countries pose a significant threat to the safe operation of the NATO forces in the waters off of potentially hostile shores. In these operations the goals of the tactical commander are to design an optimal reaction platform (formation) and to determine an optimal strategy that will help him in multi–threat encounters. The scope and design in most anti-air warfare studies have been limited to evaluating the effectiveness of detecting sensors and weapon systems in a regular screen formation. The proposed model's (Disposition Mission Model – DMM)

characterization, however, is based on how to perform an effective, defensive disposition from a task force. In DMM we focus on usage of a graphical user interface and provide a user-friendly environment for analyzing new tactics in screen formations. The model, with its user interface, allows the user to build and run a convoy simulation, and see the results comparatively on the same interface. The analysis using this model has yielded significant insights towards the defense of a convoy by way of regression methods. It has been seen that positioning the escort ships within the threat sector reduces the damage on the HVU and also balances the defensive load of each defense ship for the incoming missiles. The model, with its graphical interface and simulation components, provides an initial approach for future analysts, not only in anti-air warfare defense of screen formations, but also in the areas of anti-surface and anti-submarine warfare.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human Systems Interface

KEYWORDS: Littoral Arena, Disposition, Tactics, Simulation, Graphical User Interface, Swing

AGENT BASED SIMULATION AS AN EXPLORATORY TOOL IN THE STUDY OF THE HUMAN DIMENSION OF COMBAT

Lloyd P. Brown-Captain, United States Marine Corps
B.S., University of Arizona, 1990
Master of Science in Operations Research-March 2000
Advisor: Thomas W. Lucas, Department of Operations Research
Second Reader: Lyn R. Whitaker, Department of Operations Research

War is a human phenomenon and the essence of war is a clash between human wills. The Marine Corps is applying complexity theory to study the human dimension of land warfare with the agent based combat simulation Irreducible Semi-Autonomous Adaptive Combat (ISAAC), developed by Andrew Ilachinski. ISAAC is designed to allow the user to explore the evolving patterns of large unit behavior that result from the collective interactions of individual agents. An urban and a desert scenario were developed to explore command and control issues with ISAAC. Utilizing a personal computer and the Maui High Performance Computer Center, approximately 750,000 ISAAC runs were completed. The data are analyzed and graphically displayed using S-Plus generated Design and Trellis plots. The ISAAC data suggests there is some optimal balance between a commander's propensity to move towards the objective and his propensity to maneuver to avoid the enemy in order to minimize time to mission completion and friendly losses. Also, the data suggest that friction can significantly influence the battlefield but a strong commander-subordinate bond can reduce the effect. The exploration also demonstrated that fractional factorial designs provide almost as much information from ISAAC as full factorial designs with only a fraction of the runs.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human System Interface

KEYWORDS: ISAAC, Agent Based Simulation, Simulation, Human Dimension of Combat, Combat Models

CALCULATION OF BARRIER SEARCH PROBABILITY OF DETECTION FOR ARBITRARY SEARCH TRACKS

Wyatt J. Nash-Lieutenant, United States Navy
B.S., University of New Mexico, 1993
Master of Science in Operations Research-March 2000
Advisor: James N. Eagle, Department of Operations Research
Second Reader: Lyn R. Whitaker, Department of Operations Research

The Surface Warfare Development Group is responsible for conducting the Ship Anti-Submarine Warfare Readiness/Effectiveness Measuring Program. They currently employ a standard set of measures for evaluating the performance of shipboard anti-submarine warfare sensors. This research investigates several new performance-based measures to determine if they are more suitable than the standard measures for

evaluating the conduct of anti-submarine warfare barrier searches. The investigation simulates barrier searches to determine probability of detection, calculates the proposed measures, and compares the two. The results indicate that the proposed measures can be improved. A barrier search algorithm exploiting target-relative space ideas is developed which generalizes the classical search theory results for predicting probability of detection during barrier search.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Surface Warfare Development Group (SWDG), Shipboard Anti-Submarine Warfare Readiness/Effectiveness Measuring Program (SHAREM), Barrier Search, Modeling and Simulation, Java

A COMPARISON OF OUTPUT FROM THE LOS ALAMOS NATIONAL LABORATORY (LANL) PARALLEL OCEAN PROGRAM (POP) MODEL WITH SURFACE VELOCITY DATA FROM DRIFTING BUOYS IN THE NORTH ATLANTIC OCEAN

Jimmy W. Pelton-Lieutenant, United States Navy
B.S., North Carolina State University, 1993
Master of Science in Operations Research-March 2000
Advisors: Julie L. McClean, Department of Oceanography
Pierre-Marie Poulain, Department of Oceanography
Second Reader: Lyn R. Whitaker, Department of Operations Research

Surface velocity fields from two configurations of the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model are compared to surface velocity data from satellite-tracked buoys in the North Atlantic. Separate analyses are conducted for each model configuration. In the first analysis, output from a 1/6-degree, 20-level model version is compared with five years (1993-1997) of drifter data, based on both Eulerian and Lagrangian statistics. In the second analysis, newly-available output from a 1/10-degree, 40 level version is compared to a two-year subset (1993-1994) of the data, and to 1/6-degree output over the same time frame. The latter comparison is based on Eulerian statistics alone.

The five-year comparison shows that the 1/6-degree model produces inaccuracies in some features, and generally underestimates velocity variance. Modeled Lagrangian time scales are too long, while the length scales are too short. The two-year comparison shows that at the higher vertical and horizontal resolution of the 1/10-degree model, there is a striking improvement in the spatial distribution of energy and resolution of the variance field.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Battlespace Environments

KEYWORDS: Numerical Modeling, Ocean Forecasting, Model Evaluations

FITTING LANCHESTER AND OTHER EQUATIONS TO THE BATTLE OF KURSK DATA

Turker Turkes-First Lieutenant, Turkish Army
B.S., Turkish Army Academy, 1993
Master of Science in Operations Research-March 2000
Advisor: Thomas W. Lucas, Department of Operations Research
Second Reader: Ron Fricker, RAND Corporation

This thesis extends previous research on validating Lanchester's equations with real data. The quality of the available historical data for validation of attrition models is poor. Most accessible battle data contain only starting sizes and casualties, sometimes only for one side. A detailed database of the Battle of Kursk of World War II, the largest tank battle in history, has recently been developed. The data were collected from military archives in Germany and Russia by the Dupuy Institute (TDI) and were reformatted into a computerized data base, designated as the Kursk Data Base (KDB), and recently made available and documented in the KOSAVE (Kursk Operation Simulation and Validation Exercise of the US Army) study. The data are two-sided, time phased (daily), and highly detailed. They cover 15 days of the campaign. This thesis examines how the various derivatives of Lanchester's equations fit the newly compiled database on the Battle of Kursk. In addition, other functional forms are fit. These results are contrasted with earlier studies on the Ardennes campaign. It turns out that a wide variety of models fit the data about as well. Unfortunately, none of the basic Lanchester models fit the data, bringing into question their use in combat modeling.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Combat Modeling, Lanchester Equations, Battle of Kursk